Comparison of AC and DC LED Light Bulb Efficiency for the DC House Project

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Abstract

This project investigates the efficiency of using LED light bulbs when operated under two different electrical systems: AC and DC systems. The project is in conjunction with the implementation of the DC House system in urban areas. More specifically, this project looks at whether having a hybrid AC and DC system in a typical urban house will increase the efficiency in operating the LED light bulbs, and thus reducing energy consumption and cost. The efficiency of the LED light bulbs are measured by looking at their lumens per watt output. Several light bulbs at four different wattage levels were tested. For the DC light bulbs, further tests were performed at two voltage levels: 12V and 48V. Results indicate the importance of selecting the proper converters when DC system is to be used in a hybrid AC/DC house. Results also demonstrate the critical choice of DC voltage level when DC electrical distribution system is planned to be installed inside the hybrid house.

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1. Introduction

Today's society has become so dependent on electricity that it is now taken for granted. However, electricity is in fact not available everywhere and is not always affordable. The International Energy Agency reports there are 1.2 billion people without electricity in the world today. Of these 1.2 billion people, approximately 80% live in rural areas which remain undeveloped [2]. In order to build the infrastructure required to expand the alternating current (AC) grid and provide electricity to many of these rural areas is a costly endeavor. One solution to this problem is the establishment of micro-grids and generate the power locally and directly in the area. To achieve this, renewable resources such as photovoltaics, hydroelectric, and wind power generation can be built and placed near these communities. The direct current (DC) House project was proposed to provide a residential electrical system operating fully on DC electricity and utilizes renewable power sources to generate electricity to provide power to these remote communities.

The DC House, as the name implies, is a living environment that utilizes DC power to provide the needed electricity for light, refrigeration and many other conveniences many people in urban areas enjoy. The reason for using the DC power is mainly due to the increased popularity of residential roof-top solar panels. These solar panels produce DC electricity, so people who live in urban areas with solar panels on the roof of their house will have to convert the power generated from DC to AC power by means of an inverter. However, through the use of inverter there is an intermediate power loss that is undesirable. This power loss creates an unnecessary load on the system resulting in a greater operational cost and increase in initial build cost through the introduction of power inverters and the requirement of additional generators to make up the loss. This problem exacerbates when the load is DC such as LED lights, portable electronics, etc. Therefore, the use of DC electrical system allows the elimination of the power inverters from the solar panels which makes it more energy efficient.

The DC house provides great benefits for those who live out in the rural areas by reducing the cost to provide power and allows the creation of micro-grids for these communities. By utilizing a DC bus we can minimize the reactive power loss of low power devices such as LED light bulbs and various chargers by eliminating the need of AC to DC converter for each one. For those living in urban areas, where the power systems can be tied into the AC power grid, a simpler solution may be the use of a single AC to DC converter to provide a DC bus to provide electricity to low power devices. This leaves the higher power devices such as washing machines, dryers, and refrigerators, devices that typically have a high reactive load, powered by AC.

2. Background

The battle between AC and DC started with Edison and Tesla. The invention of the transformer enabled the transmission of power over long distances with keep down power loss on the transmission lines [4]. This allowed AC to win out since it reduced the number of power generators and increased the distance from the source that power can be sent. With current technology, namely power electronics, we can generate DC electricity locally and step up or down the voltage to make it usable for homes. This means that technology can be developed to run off of DC power and make modern conveniences available to people living in rural areas where it is too expensive to build the infrastructure for AC power to be generated and transmitted there. Because of this, the DC House project was formed in a humanitarian effort to bring low cost power to rural communities that have done without so far [3,10].

The first phase of the DC house project was started in September 2010 and completed in June 2011. This phase involved the development of designs for a Multi-input DC-DC converter, a variable voltage DC wall outlet, and power generation with Photo-voltaic, Wind, hydro-electric, and bicycle power systems. The Multi-Input Single-Output (MISO) converter is one of the key projects that was completed during this phase. The MISO DC-DC Converter allows wind, solar, hydro, bicycle, and future DC power generators to be connected to a single DC bus for the use by systems in the house or to charge a battery system [5].

The second phase of the DC house project, active from 2011 to 2012, includes the improvement of the MISO converter and DC wall outlet; as well as development of a DC light bulb, cell phone charger, and a Seesaw Human Powered Generator. The DC LED light bulb was developed and incorporated an LED driver that allowed the light bulb to function off of inputs from 24VDC to 72VDC and provides a highly efficient means of producing light. The use of LED Light bulbs as the primary light source provides highly efficient low power means of lighting the DC House [6].

The third phase of the DC house project, active from 2012 to 2013, includes the development of a DC distribution panel, portable DC light bulb, Swing Human-powered generator, Merry-Go-Round Human powered generator, and bi-directional DC-DC flyback converter. The bidirectional flyback converter enables the inclusion of a battery backup system to the DC house. Additionally, the power distribution system ensures that a proper power flow is maintained [7].

The fourth phase of the DC house project, active from 2014 to 2015, includes the development of an Arc Fault Current Interrupter (AFCI) and ventilation wind power generator, as well as improvements to the Merry-Go-Round human-powered generator, Swing human-powered generator, portable Nano hydro generator, Bi-directional DC-DC flyback converter and the DC Light bulb. The AFCI is an important addition to the DC House that improves safety as it detects when arcing occurs and responds appropriately to eliminate the arc [8].

The fifth phase of the DC House project started in September 2015 and is ongoing. The goals for this phase is the development of 3 fully functioning DC House prototypes, Development of improved swing and merry-go-round generators, and Development of an ocean-wave portable generator. The prototypes are located at Cal Poly, Universitas Padjadjaran Bandung Indonesia, and Technological Institute of the Philippines [9].

This project is part of the DC House project to investigate the efficiency of low power devices when comparing their use between AC and DC. By looking at the power usage for a device on AC and then the power usage of a DC equivalent device with a high efficiency Switch Mode Power Supply (SMPS) and comparing them. Based on the results, we can determine if using a DC light bulb or other low powered device run off of a bus powered by an SMPS is more energy efficient than running their AC counterpart. From this we can determine if a DC bus can be used to complement the existing AC system for houses in urban areas that are tied into the existing AC grid to keep electricity cost down.

3. Experiment Design

To compare the efficiency of low power devices between AC and DC counterparts, we decided to compare LED light bulbs for the purposes of the DC house in urban areas. Since light bulbs are rated by their wattage and not by their lumen output, although many have a lumen rating listed, we decided to compare the light bulbs by looking at their lumens per watt output. Since the high reactive load components will be running off of AC and the DC will be provided by a SMPS powered by AC we would look at the power used by both the SMPS and the DC light bulb vs the AC light bulb by itself.

In order to provide a consistent measurement and minimize the impact of external light sources on the measurements for light output, a box was constructed to house the standard A19 socket and block out external light sources, shown in figure 3-1.

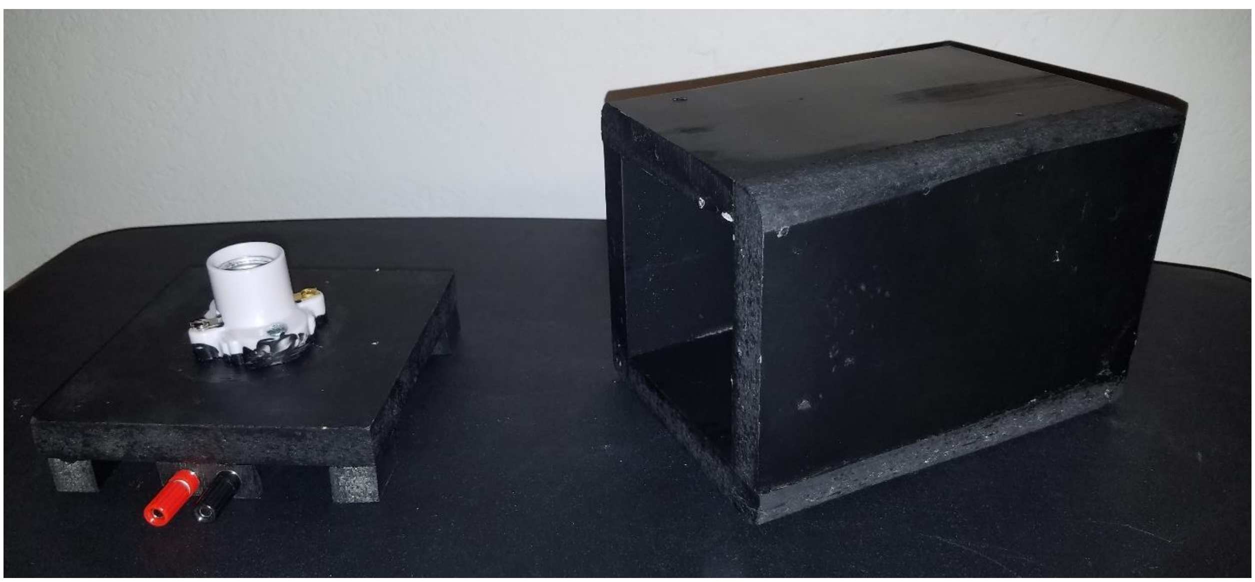

Figure 3-1 Experimental Box

The box was constructed out of scrap wood to keep cost down. The A19 socket was wired to 2 female banana plugs to allow for use with both AC and DC power sources. A hole was drilled into the top of the box, as shown in Figure 3-2, to provide an opening to mount the light sensor of the lux meter.

Figure 3-2 Top of box with opening for light sensor

The opening was sized to the light sensor aperture on the lux meter to minimize the amount of external light entering the box and allow for more accurate measurements. The block diagram in Figure 3-3 shows the experiment design as collected.

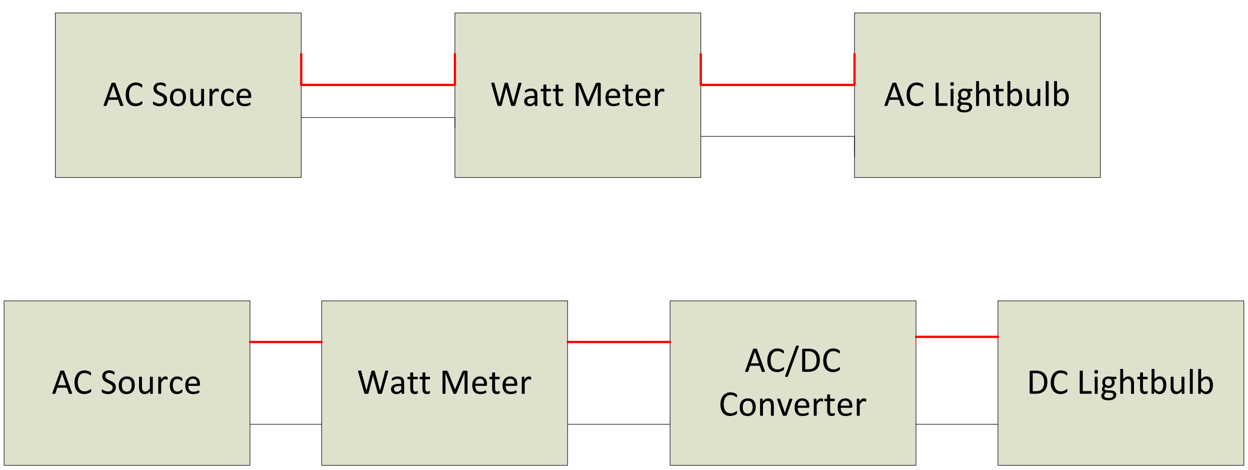

Figure 3-3 Block diagram for AC light bulb test (top) and DC light bulb test (bottom)

Figure 3-4 shows the laboratory setup for the data collection of the DC light bulbs.

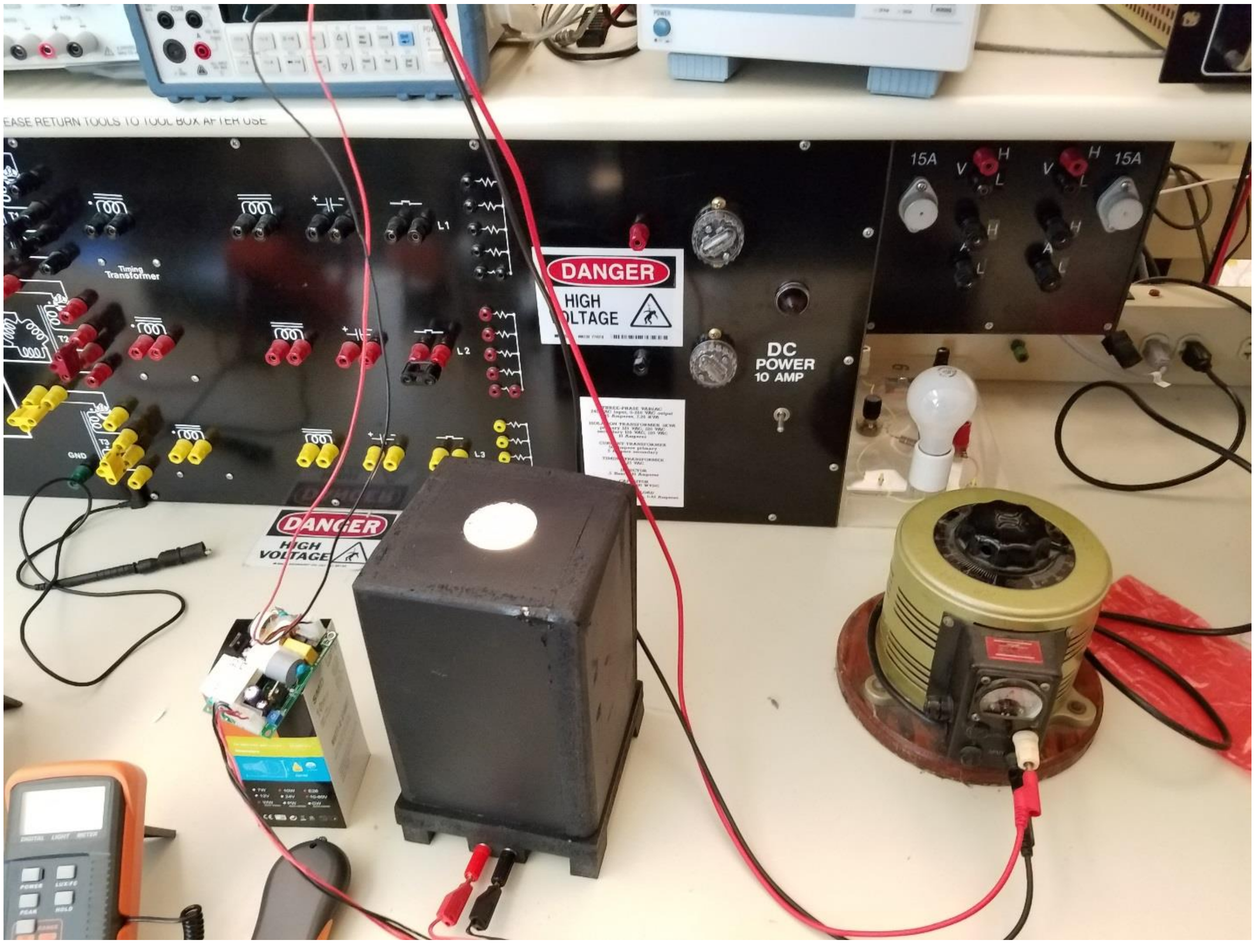

Figure 3-4 Experiment setup for DC input.

To provide sufficient data, light bulbs with varying wattage voltage levels at 12V and 48V were selected. There were 4 options for light bulb wattage for the DC light bulb: 3W, 5W, 7W, and 10W. Again to minimize cost, 3 power levels were chosen: the 3W, 5W, and 10W, and their AC equivalents. The SMPS power supply for the DC light bulbs was chosen as a 25W 90% efficient AC/DC converter that outputs 48V and a second one that outputs 12V. Tables 3-1 to 3-6 show a cost assessment of each design that was considered. The design chosen was Table 3-1, having more than a single light bulb to test provides additional data as the lumens output and power usage of each light can vary.

Table 3-1 Two light bulbs at 3W, 5W, and 10W for 120Vac, 48Vdc and 12Vdc

	Qty	Cost/unit	Total Cost
3W 48Vdc Light bulb	2	$16.85	$33.70
3W 12Vdc Light bulb	2	$15.85	$31.70
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	2	$20.25	$40.50
5W 12Vdc Light bulb	2	$19.65	$39.30
5W AC Light bulb (2 count)	1	$14.99	$14.99
10W 48Vdc Light bulb	2	$25.65	$51.30
10W 12Vdc Light bulb	2	$22.50	$45.00
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
AC/DC Converter 12V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$372.22

Incidentally, the ordered DC Light bulbs received were 12V-80V DC light bulbs which allowed for more data to be collected for each of the DC cases, but may have an impact on the bulbs LED efficiency.

Table 3-2 A single light bulb at 3W, 5W, 7W, and 10W for 120Vac, 48Vdc and 12Vdc

	Qty	Cost/unit	Total Cost
3W 48Vdc Light bulb	1	$16.85	$16.85
3W 12Vdc Light bulb	1	$15.85	$15.85
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	1	$20.25	$20.25
5W 12Vdc Light bulb	1	$19.65	$19.65
5W AC Light bulb (2 count)	1	$14.99	$14.99
7W 48Vdc Light bulb	1	$23.85	$23.85
7W 12Vdc Light bulb	1	$21.80	$21.80
7W AC Light bulb (2 count)	1	$19.99	$19.99
10W 48Vdc Light bulb	1	$25.65	$25.65
10W 12Vdc Light bulb	1	$22.50	$22.50
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
AC/DC Converter 12V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$317.11

Table 3-3 Two light bulbs at 3W, 5W, 7W, and 10W at 120Vac, 48Vdc and 12Vdc

	Qty	Cost/unit	Cost
3W 48Vdc Light bulb	2	$16.85	$33.70
3W 12Vdc Light bulb	2	$15.85	$31.70
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	2	$20.25	$40.50
5W 12Vdc Light bulb	2	$19.65	$39.30
5W AC Light bulb (2 count)	1	$14.99	$14.99
7W 48Vdc Light bulb	2	$23.85	$47.70
7W 12Vdc Light bulb	2	$21.80	$43.60
7W AC Light bulb (2 count)	1	$19.99	$19.99
10W 48Vdc Light bulb	2	$25.65	$51.30
10W 12Vdc Light bulb	2	$22.50	$45.00
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
AC/DC Converter 12V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$483.51

Table 3-4 A single light bulb at 3W, 5W, and 10W for 120Vac, 48Vdc and 12Vdc

	Qty	Cost/unit	Total Cost
3W 48Vdc Light bulb	1	$16.85	$16.85
3W 12Vdc Light bulb	1	$15.85	$15.85
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	1	$20.25	$20.25
5W 12Vdc Light bulb	1	$19.65	$19.65
5W AC Light bulb (2 count)	1	$14.99	$14.99
10W 48Vdc Light bulb	1	$25.65	$25.65
10W 12Vdc Light bulb	1	$22.50	$22.50
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
AC/DC Converter 12V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$251.47

Table 3-5 A single light bulb at 3W, 5W, 7W, and 10W for 120Vac and 48Vdc

	Qty	Cost/unit	Total Cost
3W 48Vdc Light bulb	1	$16.85	$16.85
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	1	$20.25	$20.25
5W AC Light bulb (2 count)	1	$14.99	$14.99
7W 48Vdc Light bulb	1	$23.85	$23.85
7W AC Light bulb (2 count)	1	$19.99	$19.99
10W 48Vdc Light bulb	1	$25.65	$25.65
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$212.31

Table 3-6 Two Light bulbs at 3W, 5W, 7W, and 10W for 120Vac and 48Vdc

	Qty	Cost/unit	Total Cost
3W 48Vdc Light bulb	2	$16.85	$33.70
3W AC Light bulb (6 count)	1	$16.99	$16.99
5W 48Vdc Light bulb	2	$20.25	$40.50
5W AC Light bulb (2 count)	1	$14.99	$14.99
7W 48Vdc Light bulb	2	$23.85	$47.70
7W AC Light bulb (2 count)	1	$19.99	$19.99
10W 48Vdc Light bulb	2	$25.65	$51.30
10W AC Light bulb (3 Count)	1	$14.95	$14.95
Pass & Seymour White Medium Base Cleat Lamp Socket	1	$2.99	$2.99
Lux Meter	1	$18.99	$18.99
AC/DC Converter 48V (25W)	1	$25.00	$25.00
Molex 09-50-10-31	2	$0.45	$0.90
Molex 09-50-10-41	2	$0.26	$0.52
SPOX 5194	14	$0.10	$1.40
Hookup Wire 20AWG	1	$8.99	$8.99
		Total:	$298.91

4. Data and Results

During the experiment, as many as 4 measurements were made for each bulb. Power in, Lux, color temperature, and Distance from the LEDs to the lux sensor is shown in Table 4-1.

Table 4-1 Data with bulb attached

Bulb	Type	Pin (W)	Distance (cm)	Color Temperature (K)	Lux	Lumens
10W	120Vrms	9	12.4	2890K	9340	902.340
10W	120Vrms	8.96	12.4	2884K	9960	962.238
10W	120Vrms	9	12.4	2886K	10650	1028.899
5W	120Vrms	4.37	13.3	3008K	4140	460.133
5W	120Vrms	4.48	13.3	3068K	4170	463.467
5W	120Vrms	4.24	13.3	3049K	3960	440.127
3W	120Vrms	4.28	13.9	2799K	2030	246.437
3W	120Vrms	4.37	13.9	2793K	2040	247.651
3W	120Vrms	4.25	13.9	2795K	1990	241.581
10W	48 Vdc	11.38	10.7	2942K	15200	1093.430
10W	48 Vdc	10.61	10.7	2942K	14900	1071.849
10W	48 Vdc	11.08	10.7	2925K	15300	1100.624
5W	48 Vdc	7.13	13.2	2990K	5540	606.509
5W	48 Vdc	7.02	13.2	2978K	5550	607.604
5W	48 Vdc	7.07	13.2	2970K	5600	613.078
3W	48 Vdc	4.6	14.1	3021K	2190	273.566
3W	48 Vdc	4.62	14.1	3085K	2190	273.566
3W	48 Vdc	4.41	14.1	3061K	2130	266.071
10W	12 Vdc	11.81	10.7	2930K	15600	1122.205
10W	12 Vdc	11.04	10.7	2932K	14800	1064.656
10W	12 Vdc	11.4	10.7	2935K	15100	1086.236
5W	12 Vdc	7.27	13.2	2985K	5900	645.922
5W	12 Vdc	7	13.2	2957K	5659	619.537
5W	12 Vdc	7.33	13.2	2973K	5760	630.595
3W	12 Vdc	4.73	14.1	3022K	2360	294.802
3W	12 Vdc	4.6	14.1	3096K	2280	284.808
3W	12 Vdc	4.34	14.1	3076K	2150	268.569

The same measurements were then made again with the plastic bulb removed and the LEDs exposed, this data is shown in Table 4-2.

Table 4-2 Data collected for LED light bulb without bulb

Bulb	Type	Pin (W)	Distance (cm)	Color Temperature	Lux	Lumens
10W	120Vrms	9	12.4	2999K	17200	1661.696
10W	120Vrms	8.96	12.4	2966K	18440	1781.493
10W	120Vrms	9	12.4	2982K	18660	1802.747
5W	120Vrms	4.37	13.3	3135K	7260	806.900
5W	120Vrms	4.48	13.3	3136K	7400	822.460
5W	120Vrms	4.24	13.3	3120K	7050	783.560
3W	120Vrms	4.28	13.9	2870K	4220	512.297
3W	120Vrms	4.37	13.9	2820K	4450	540.218
3W	120Vrms	4.25	13.9	2850K	4340	526.865
10W	48 Vdc	11.38	10.7	3023K	24000	1726.468
10W	48 Vdc	10.61	10.7	3019K	23200	1668.919
10W	48 Vdc	11.08	10.7	3013K	23800	1712.081
5W	48 Vdc	7.13	13.2	3082K	9330	1021.431
5W	48 Vdc	7.02	13.2	3106K	9350	1023.621
5W	48 Vdc	7.07	13.2	3083K	9300	1018.147
3W	48 Vdc	4.6	14.1	3096K	5060	632.075
3W	48 Vdc	4.62	14.1	3194K	5040	629.576
3W	48 Vdc	4.41	14.1	3152k	4940	617.085
10W	12 Vdc	11.81	10.7	3023K	24400	1755.243
10W	12 Vdc	11.04	10.7	3030K	23400	1683.307
10W	12 Vdc	11.4	10.7	3032K	23500	1690.500
5W	12 Vdc	7.27	13.2	3102K	9660	1057.559
5W	12 Vdc	7	13.2	3100K	9460	1035.664
5W	12 Vdc	7.33	13.2	3100K	9610	1052.086
3W	12 Vdc	4.73	14.1	3102K	5360	669.549
3W	12 Vdc	4.6	14.1	3193K	5250	655.809
3W	12 Vdc	4.34	14.1	3165K	5330	665.802

Based on the limited fluctuation in color temperature, it was concluded that it will have limited impact on the lux readings.

Since Lux is a measurement of Lumens per square meter, to calculate the Lumens from the Lux measurement in Table 4-1 and Table 4-2 equations 4-1 was used.

$$Eq\ 4-1 \qquad M = \varphi * A$$

where ϕ is Luminous flux in lumens, M is luminous emittance in lux, and A is surface area in square meters.

To calculate the surface area for the lux measurement, it was assumed that the light projected out in front of the bulb equally distributed in a half-sphere. The equation 4-2 is used to calculate the surface area of a half sphere. And equation 4-3 is equations 4-1 and 4-2 combined and used to calculate the Lumens of each bulb.

$$Eq\ 4-2 \qquad A = \frac{4 * \pi * r^2}{2}$$

$$Eq\ 4-3 \qquad \varphi = \frac{2M}{(4 * \pi * r^2)}$$

Table 4-3 Average percent increase of Lumens compared to AC light bulb.

	10W (%)	5W (%)	3W (%)
48VDC	12.871	33.985	10.539
12VDC	13.120	39.035	15.294

Table 4-4 Average percent increase of power usage compared to AC light bulb.

	10W (%)	5W (%)	3W (%)
48VDC	22.663	62.108	5.659
12VDC	27.040	65.011	5.969

$$Eq\ 4-4 \qquad \%_{diff} = \frac{DC_{avg} - AC_{avg}}{AC_{avg}}$$

Equation 4-4 was used to determine the increase in lumens output and power usage for the DC light bulb relative to the AC light bulb.

Lumens vs. Watts was then plotted trend lines added as shown in Figures 4-1 and 4-2.

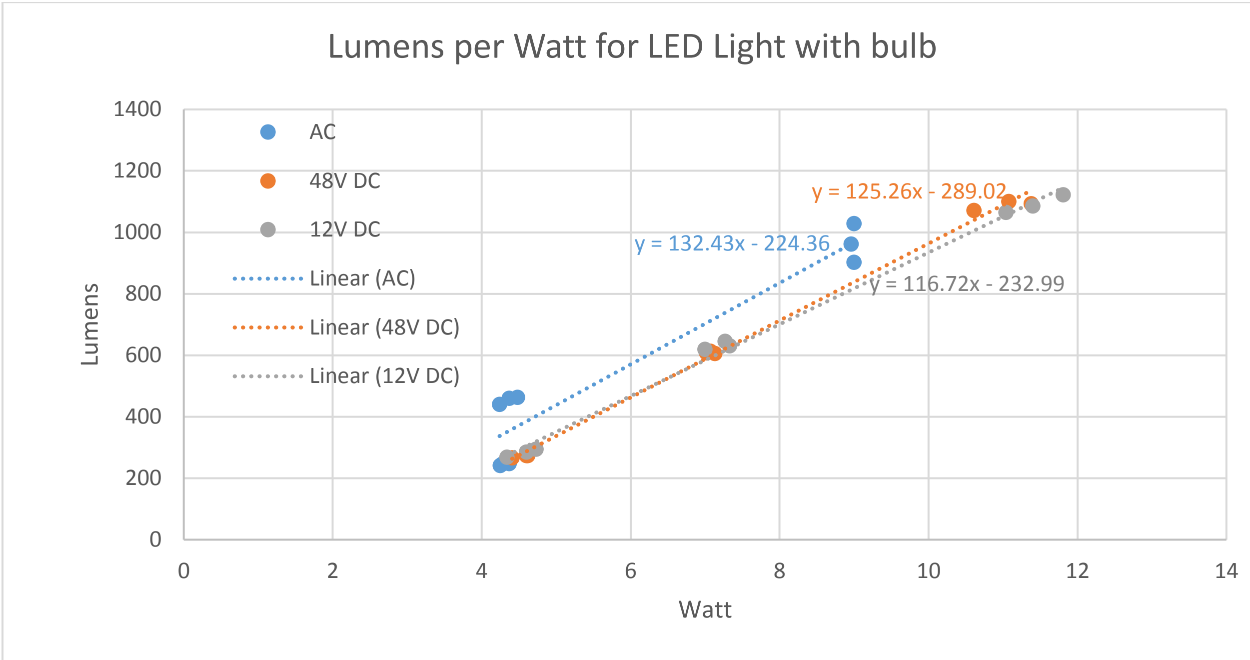

Figure 4-1 Lumens per watt plot with trend lines for LED Lights with bulb

Figure 4-1 on the last page, shows a linear increase in the Lumens/Watt of the DC light bulbs, but not the AC light bulbs. The 12VDC Light bulbs produces slightly more Lumens/Watt than the 48VDC at 3W, but at 10W the 48VDC produces more lumens/watt. At 3W the AC and DC light bulbs are roughly equivalent, but the AC light bulbs outperform the DC light bulbs at 5W and 10W.

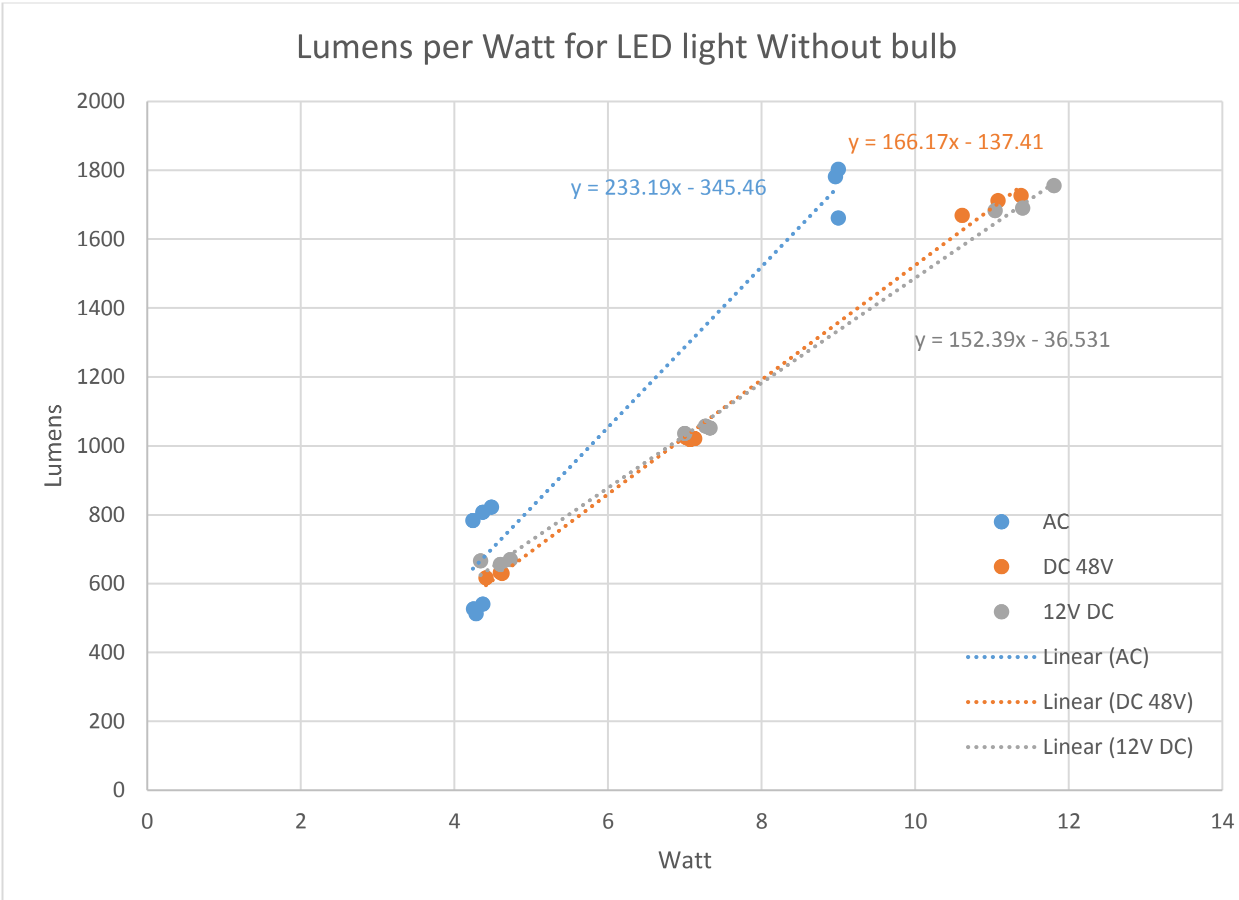

Figure 4-2 LED light plot with Trend lines without bulb

Figure 4-2 shows the same results as figure 4-1. The difference between Figure 4-1 and 4-2 is the Lumens output. By removing the plastic dome from the LED light bulbs the Lumens/Watt increases, this increase slightly intensifies the difference of the Lumens/Watt for the entire plot.

Due to the similarity in power usage of the AC 3W and 5W bulbs, Figures 4-3 and 4-4 were plotted omitting the 3W data points to provide a better fitting trend line for the data provided.

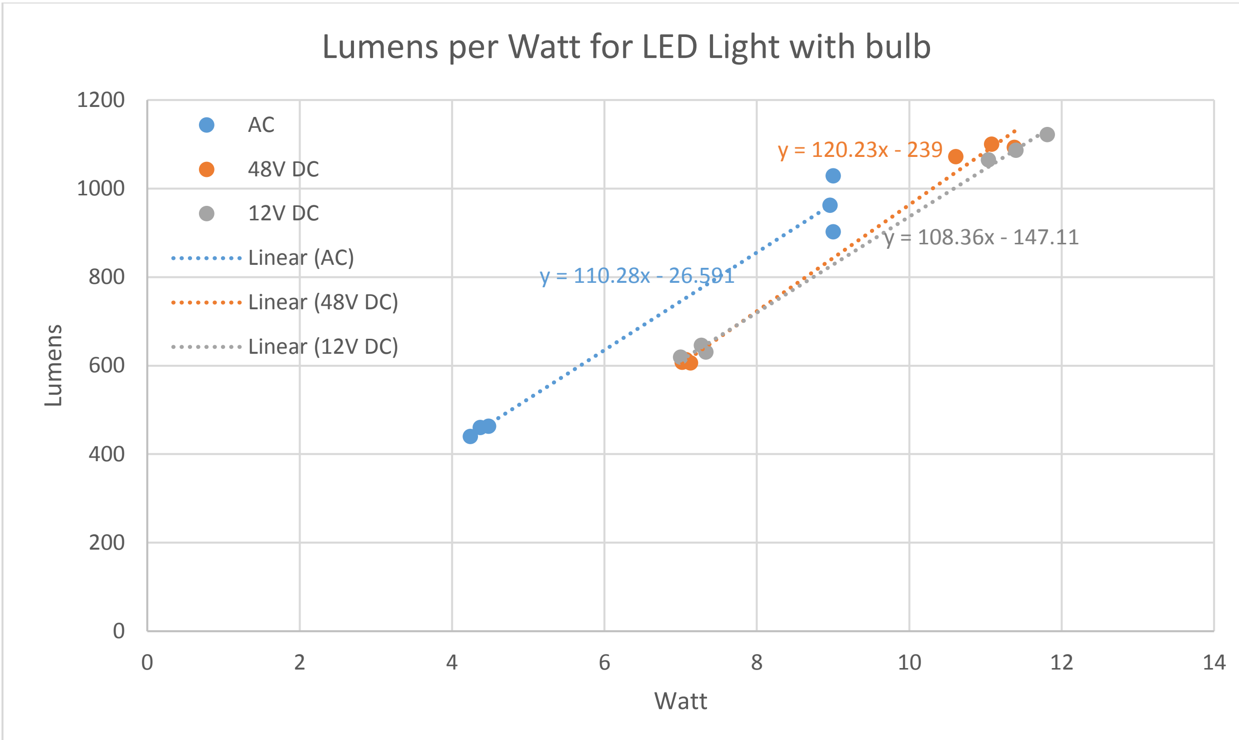

Figure 4-3 Lumens vs Watt for 5W and 10W LED light with bulb

Figure 4-3 shows that DC light bulbs produce more Lumens, but use more Watts to achieve it. However, the AC light bulbs produce more Lumens/Watt than the DC. Based on the slope of the trend lines in figure 4-3 the DC will at some point produce more Lumens/Watt than the AC bulbs with the 48VDC light bulbs achieving that crossing before the 12VDC light bulbs.

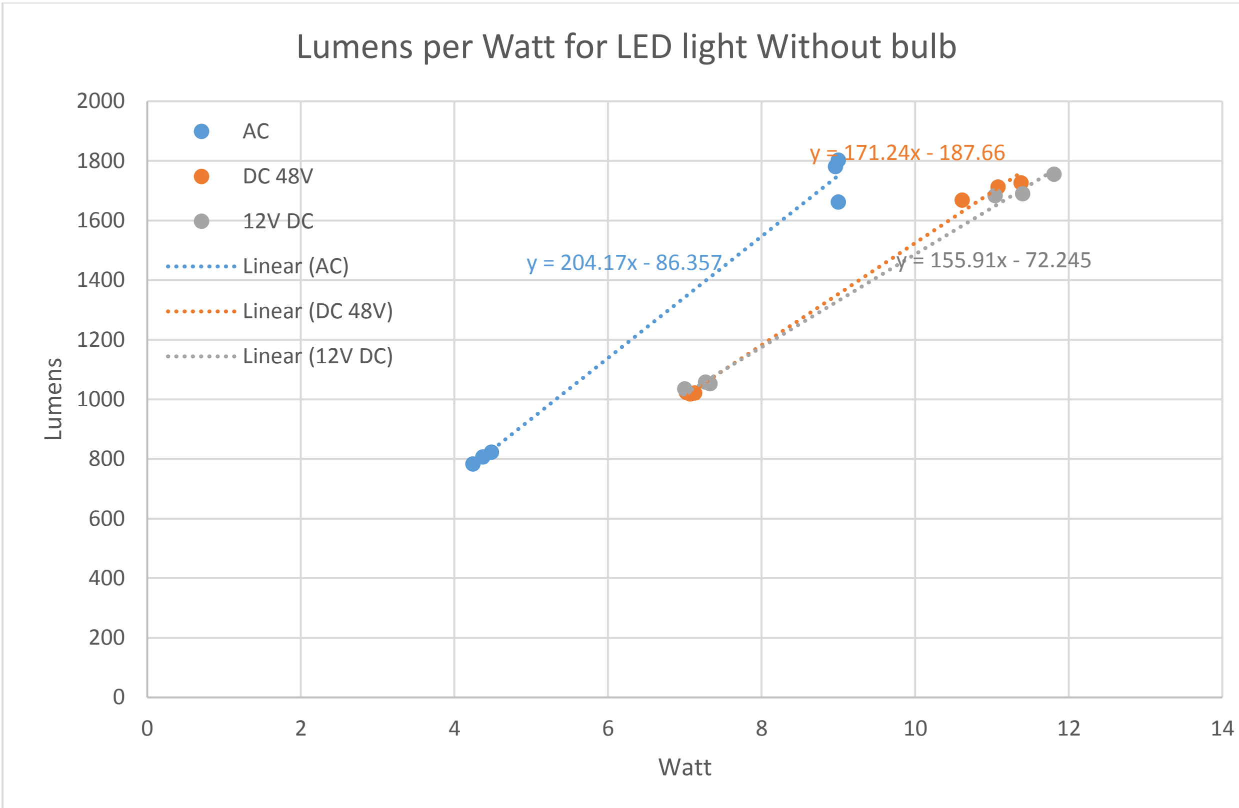

Figure 4-4 Lumens vs Watt for 5W and 10W LED light without bulb

Figure 4-4 shows that 5W AC bulbs produce fewer lumens at lower watts than the 5W DC bulb, but the 10W AC produces the same amount of lumens at a lower wattage than the 10W DC bulb. The slope of the trend line on figure 4-4 shows that the AC light bulb will maintain its higher lumens per watt than the DC light bulbs.

5. Conclusion and Further Work

With current light bulb technology, to run an AC LED light bulb straight off of an AC system is more energy efficient than running a DC light bulb off of a high efficiency AC to DC SMPS. The DC light bulbs in general produced more Lumens at their respective ratings with an average increase of 19.1% at $48V_{DC}$ and 22.5% at $12V_{DC}$. However, the DC light bulbs used an average of 30.1% more power at $48V_{DC}$ and 32.7% more power at $12V_{DC}$. Though the DC Light bulbs produce more lumens, the energy cost to do so outweighs the increase making the AC bulbs more energy efficient.

The similar power usage of the 3W bulb and 5W bulbs for AC skews the trend line making it difficult to extrapolate if there is a point where the DC will perform better than the AC bulb for loading. However, by omitting the 3W bulb from the data as shown in Figures 4-3 and 4-4, a better fitting trend line can be seen. Using the 5W and 10W bulbs only, and using Figure 4-3 it appears that the DC light bulbs will prove more efficient as you increase the number of bulbs but Figure 4-4 contradicts this. Comparing Figure 4-3 and 4-4 suggests that a more efficient SMPS, such as one rated at 95% efficiency, is enough to make the DC light bulbs with an SMPS a stronger answer as this would increase the slope for the DC light bulbs in each of the graphs shown in Figures 4-1 through 4-4.

For the 12V DC compared the 48V DC bus, Figures 4-1 through 4-4 show that the 48V bus is more efficient than the 12V bus when using a 10W bulb and equivalent when using a 5W bulb. Figures 4-1 and 4-2 show that for a 3W bulb a 12V DC bus was more efficient than on the 48V bus. This indicates that as the power draw increases the 48V DC bus is more efficient than the 12V DC bus.

There are two ways to expand this data for more conclusive results. The first is by looking at the impact of the SMPS efficiency on the system and, if possible, determine an optimal efficiency for the SMPS used. The second is by looking at the impact of multiple light bulbs and determine the minimum number of LED light bulbs to use before the DC system becomes more efficient than the AC system.

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Appendix A – Analysis of Senior Project Design

Project Title: Comparison of AC and DC LED Light Bulb Efficiency for the DC House Project

Student's Name: Brandon Stafford **Student's Signature:**

Advisor's Name: Taufik **Advisor's Initials:** T **Date:** 1/10/17

Summary of Functional Requirements

This project provides a means of collecting energy usage and lux output for LED Lightbulbs for both AC and DC Light bulbs.

Primary Constraints

Since light bulbs are rated based on their power usage and not the lumens output, I needed to design a system that could provide a meaningful relationship of the efficiency of LED light bulbs. Simply hooking up a series of LED bulbs and looking at how the number of bulbs impacted the power usage of the system would not provide meaningful data as this would characterize the switch mode power supply instead of providing data on if using DC LED light bulbs is more energy efficient than AC light bulbs. The next requirement was to provide a system that would allow for reliable collection of data on the light output. Isolating the light bulb from the rest of the room so the only light source was the light bulb eliminated the influence of daylight or from other light sources in the lab.

Economic

The project demonstrates that when powering a light bulb off of a grid tied AC line that using AC lightbulbs is more efficient. Incorporating a switch mode power supply increases the upfront cost with no benefits to saving energy for use of lightbulbs. The benefits show at the end of the project life cycle when it determines if DC light bulbs are more efficient than AC light bulbs. The cost was covered by the project participant. Table 3-1 shows the initial cost, final cost and the bill of materials.

Commercial Basis

This project has no known target market and is not expected to be produced again as there are superiors devices that can be used to provide the same data. The price of such existing devices is not in the budget for use of this project. To produce this device, it is estimated to be approximately $83. This omits the cost of the light bulbs that are used for testing.

Environmental

This project has minimal environmental impact as it is for use with existing infrastructure. This setup makes use power generation that already exists for the AC grid. The outcome of this project is to determine a means of minimizing power usage to provide lighting or other low energy devices and thus reduce the amount of fossil fuels used for power generation such as coal and natural gas. By minimizing the use of fossil fuels for energy production, we can minimize the harm to the environment that burning these fuels has.

Manufacturability

There are few limitations on the manufacturability for this project. The components used are readily available from manufacturers and easy to obtain. Aside from the switch mode power supply, the design is simple, and since the SMPS is purchased and not built, it is easy to obtain.

Sustainability

The maintenance of the device will be relatively simple as the primary component that will fail is the SMPS and it is easy to switch out and it can be recycled or stripped of working parts. The only improvement for this system would be a more efficient SMPS

Ethical

Since this project is a comparison of AC LED light bulbs and DC LED light bulbs, if this project were to go into mass production for use by the end user it would result in an increased cost in both electricity and materials used. As the project was designed, there is next to no ability to misuse the project and manufacturing has no ethical problems beyond the existing health risk of using the tools necessary to build the apparatus.

Health and Safety

The primary concerns for health and safety for the manufacture and use of this project is the potential of cutting or crushing from use of power tools to shape the enclosure and burning from soldering. As with any offline device, it also presents a potential fire and electrocution risk from offline power. The fire and electrocution risk is mitigated by the use of insulated wires.

Social and Political

This project impacts any end user who utilizes LED light bulbs. By determining if AC LED light bulbs or DC LED light bulbs with an SMPS will effect manufacturers of both kinds of LED light bulbs, as well as power companies and the manufacturers of SMPSs. By minimizing the power used reduces the amount of power required impact the profit margin of power companies as well as affecting costs and production of AC LED light bulbs and DC LED light bulbs.

Development

While developing this project, I looked into how light was measured and how to use these measurements to determine the efficiency of light bulbs, in particular LED light bulbs, in their conversion of watts to lumens. This required learning how to calculate the approximate lumens output based on a lux reading.